What are possible definitions of "reliability" that have been used or proposed for use by policy makers? What studies exist regarding the economic and environmental benefits of baseline or "additional" reliability?

For most discussions of "reliability", the definitions used by power system engineers to describe bulk power and longer time frames would also be used by policy makers. These look at distinct time horizons and large-scale components of the power system. The usual measure of reliability for both generation and delivery is capacity to serve customer demand for electricity, or "load." Thus, more ways to keep the supply adequate for a given level of load, or the ability to meet a higher level of load would be recognized as increased reliability. Common examples are the reliability or adequacy of the power supply for the forecasted needs for the coming year, or the reliability of the transmission system to deliver enough power to the Upper Peninsula. In these terms, the economic benefits of adding reliability would generally be found in a comparison to the cost of an incremental expansion of capacity using an identified avoided generating plant or transmission solution.

Additional policy-oriented definitions of reliability are those that consider future scenarios of concern to the public, such as systemic disruption or stress from a macro-scale external event, such as drought or fuel supply disruption. This type of reliability study has become more relevant in recent years as power system interdependencies and vulnerabilities to extreme weather have been recognized as threats to reliability.

The Union of Concerned Scientists has released a study of the risks to reliability, and related economic and environmental benefits from increasing the use of renewable energy generation. The latest UCS report describes the economic disadvantage of continued operation of seven coal plants in Michigan, and the savings of over 5 billion gallons of *consumed* water if these plants are replaced with renewable energy and energy efficiency.

More generally, the Midwest ISO uses two approaches to defining the benefits of additional transmission, and the reliability benefits of additional wind generation.

1. Transmission

Transmission costs and benefits are assessed by Midwest ISO and discussed with stakeholders. In 2010-2011, Midwest ISO defined and approved a portfolio of transmission upgrades to accommodate generation connections and improve reliability in Michigan and across the MISO footprint. The first package of 17 Multi-Value Projects was described by Midwest ISO as "having benefits in excess of the portfolio cost under all scenarios studied. These benefits are spread throughout the system, and each zone receives benefits of at least 1.6 and up to 2.8 times the costs it incurs." MTEP 11, page 1. https://www.midwestiso.org/_layouts/MISO/ECM/Redirect.aspx?ID=120701

2. Generation

The Midwest ISO also has an explicit process for establishing the reliability benefits of new generation. This involves calculating the Loss of Load Expectation (LOLE) for a specific set of generators and energy demand patterns. The idea is that adding more energy sources increases the probability that there will be enough generated energy when a shortage threatens reliability. An increase in this measure generally follows when additional generation is included, and that increase for the specific generator is the Effective Load-Carrying Capability (ELCC). The MISO uses ELCC for wind and has done so for 3 years. See this year's report at
https://www.midwestiso.org/Library/Repository/Study/LOLE/2013%20Wind%20Capacity%20Report.pdf

Below is description of the steps for finding the reliability benefits from wind from a U.S. Department of Energy-funded research paper: Milligan, M. and Porter, K. 2005. *Determining the Capacity Value of Wind: A Survey of Methods and Implementation*. Golden, CO: National Renewable Energy Laboratory. http://www.nerc.com/docs/pc/ivgtf/milligan_porter_capacity_paper_2005.pdf

ELCC is calculated in several steps. To calculate ELCC, a database is required that contains hourly load requirements and generator characteristics. For conventional generators, rated capacity, forced outage rates, and specific maintenance schedules are primary requirements. For wind, an intermittent resource, at least 1 year of hourly power output is required, but more data is always better. Most commonly, the system is modeled without the generator of interest. For this discussion, we assume that the generator of interest is a renewable generator, but this does not need to be the case. The loads are adjusted to achieve a given level of reliability. This reliability level is often equated to a loss of load expectation (LOLE) of 1 day per 10 years. This LOLE can be calculated by taking the LOLP (a probability is between zero and one and cannot by definition exceed 1) multiplied by the number of days in a year. Thus LOLE indicates an expected value and can be expressed in hours/year, days/year, or other unit of time.

Once the desired LOLE target is achieved, the renewable generator is added to the system and the model is re-run. The new, lower LOLE (higher reliability) is noted, and the generator is removed from the system. Then the benchmark unit is added to the system in small incremental capacities until the LOLE with the benchmark unit matches the LOLE that was achieved with the renewable generator. The capacity of the benchmark unit is then noted, and that becomes the ELCC of the renewable generator. It is important to note that the ELCC documents the capacity that achieves the same risk level as would be achieved without the renewable generator.

Resources:

1) Fleishman, L and Schmoker, M. 2013 *Economic and Water Dependence Risks for America's Aging Coal Fleet.* Cambridge, MA: Union of Concerned Scientists. April. Online at http://www.ucsusa.org/assets/documents/clean_energy/Water-Dependence-Risks-for-America-s-Aging-Coal-Fleet.pdf; accessed April 8, 2013.